

Toward an Improved Ozone Profile Algorithm for the Airborne GeoTASO Sensor

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Paper No. 572
Paper Reference 4.24

EUMETSAT 2017
02 – 06 October 2017
Rome, Italy

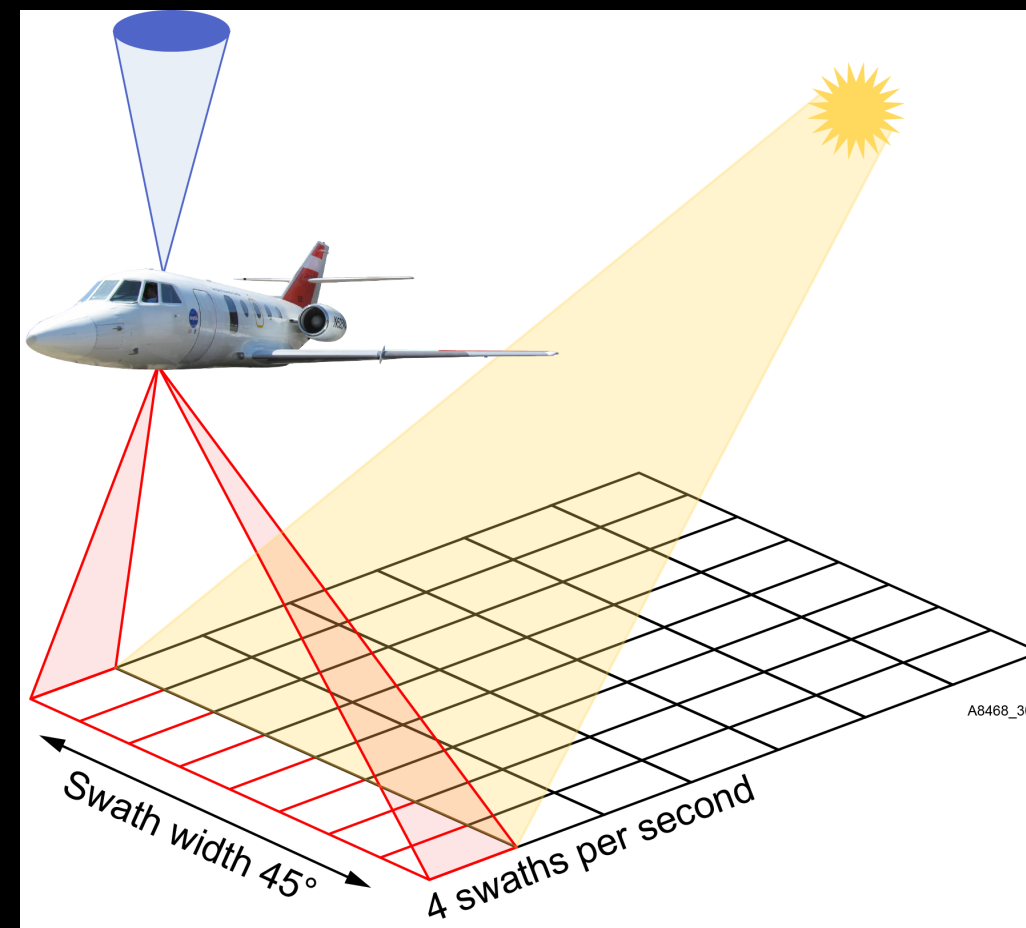
Acknowledgements The authors would like to thank C. Nowlan (SAO), Jim Leitch (Ball Aerospace), S. Janz and M. Kowalewski (NASA GSFC), and J. Al-Saadi (NASA Langley) for helpful discussions. This work is funded by NASA's GEO-CAPE project.

Overview

The Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) is an airborne UV/Visible CCD spectrometer that was developed in support of the upcoming US TEMPO EV-I mission. Like TEMPO, the instrument was built by Ball Aerospace. The GeoTASO spectrometer consists of two channels that cover the spectral ranges of 290–400 nm and 415–695 nm with 0.28-0.49 nm (UV) and 0.56-0.98 nm (Visible) spectral resolution. At a typical flight altitude of 11 km, the 45° field of view results in a ~9 km wide swath subdivided into 1000 cross-track pixels for a 9m across-track footprint size. The instantaneous field of view records ground pixels of 50-80 m along-track, depending on detector integration time and aircraft speed relative to ground. The main observation is nadir, with occasional measurements in upward-looking zenith-sky geometry for an above-aircraft reference spectrum (image courtesy of C. Nowlan, SAO [1]).

GeoTASO observation targets include ozone, SO₂, NO₂, H₂CO, C₂H₂O₂, and aerosols. Deployments to date include DISCOVER-AQ campaigns in Houston, TX (2013) and Denver, CO (2014), an Ocean Color Study (2015), and the 2016 KORUS-AQ campaign in Korea. The results presented here are use data taken on 2014-08-02 during the 2014 DISCOVER-AQ campaign.

[1] Nowlan *et al.*, Nitrogen dioxide observations from the Geostationary Trace gas and Aerosol Sensor Optimization (GeoTASO) airborne instrument: Retrieval algorithm and measurements during DISCOVER-AQ Texas 2013, Atmos. Meas. Tech., 9, 2016.



Retrieval Approach

CARVE As part of the GEO-CAPE project, JPL has been developing retrieval algorithms for NO₂ columns and ozone profiles from GeoTASO observations. The retrieval approach is based on OMI algorithm heritage in an improved implementation, using state-of-the-art non-linear least squares minimization techniques, and with built-in flexibility to perform trace gas retrievals on airborne (*e.g.*, GeoTASO), satellite (*e.g.*, OMI, OMPS), and ground-based observations. The spectral fitting modules will be combined with new advancements in LIDORT-based [2] fast radiative transfer developed by V. Natraj that eliminates the need for tabulated air mass factors.

We present preliminary results of NO₂, O₃ and O₂-O₂ semi-slant geometric columns, i.e., slant column densities divided by the cosine of the solar zenith angle, from the AM and PM flights on 2014-08-02. GeoTASO spectra were co-added to ~250x250 m² prior to the spectral fitting. Fitting windows were selected as 320—340 nm (O₃), 425—455 nm (NO₂), and 442—488 nm (O₂-O₂). Retrievals were performed against an external solar reference [3] rather than a GeoTASO radiance measurement.

[2] Spurr&Natraj, A linearized two-stream radiative transfer code for fast approximation of multiple-scatter fields, J. Quant. Spec. Rad. Trans., 112, 2011.

[3] Chance&Kurucz, An improved high-resolution solar reference spectrum for earth's atmosphere measurements in the ultraviolet, visible, and near infrared, J. Quant. Spec. Rad. Trans. 111, 2010.

NO₂ Columns, Visible Channel

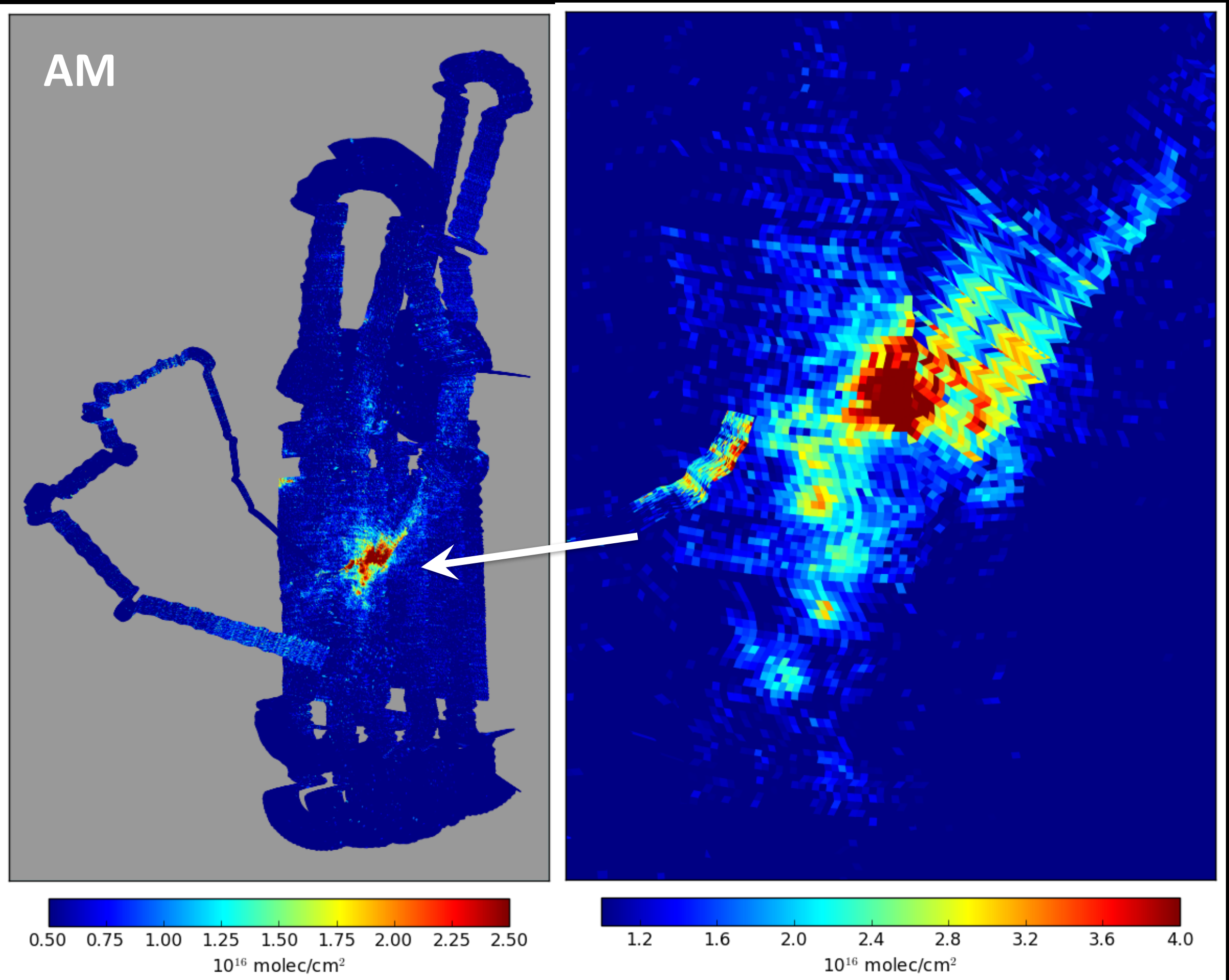
NO₂ turns out to be the most readily retrievable target gas from GeoTASO: the visible channel is well calibrated, with little cross-track bias. Some residual along-track striping, a common problem with CCD detectors, is noticeable.

Images show select AM and PM flight tracks during the 2014 Denver flight campaign, including spatial zooms over the Denver metro area (note the different ranges in color scale between full-scale and zoom images). The 250x250 m² spatial resolution of the retrievals easily resolves hot spots within cities.

More recently, GeoTASO participated in the KORUS-AQ (Korea-US Air Quality) campaign as part of the GEMS validation activities. The instrument was flown in a slightly modified configuration, and the available level-2 spectra from KORUS-AQ are still preliminary (*e.g.*, no dark current correction). This explains the slightly more prominent presence of along-track stripes for some of the cross-track positions.

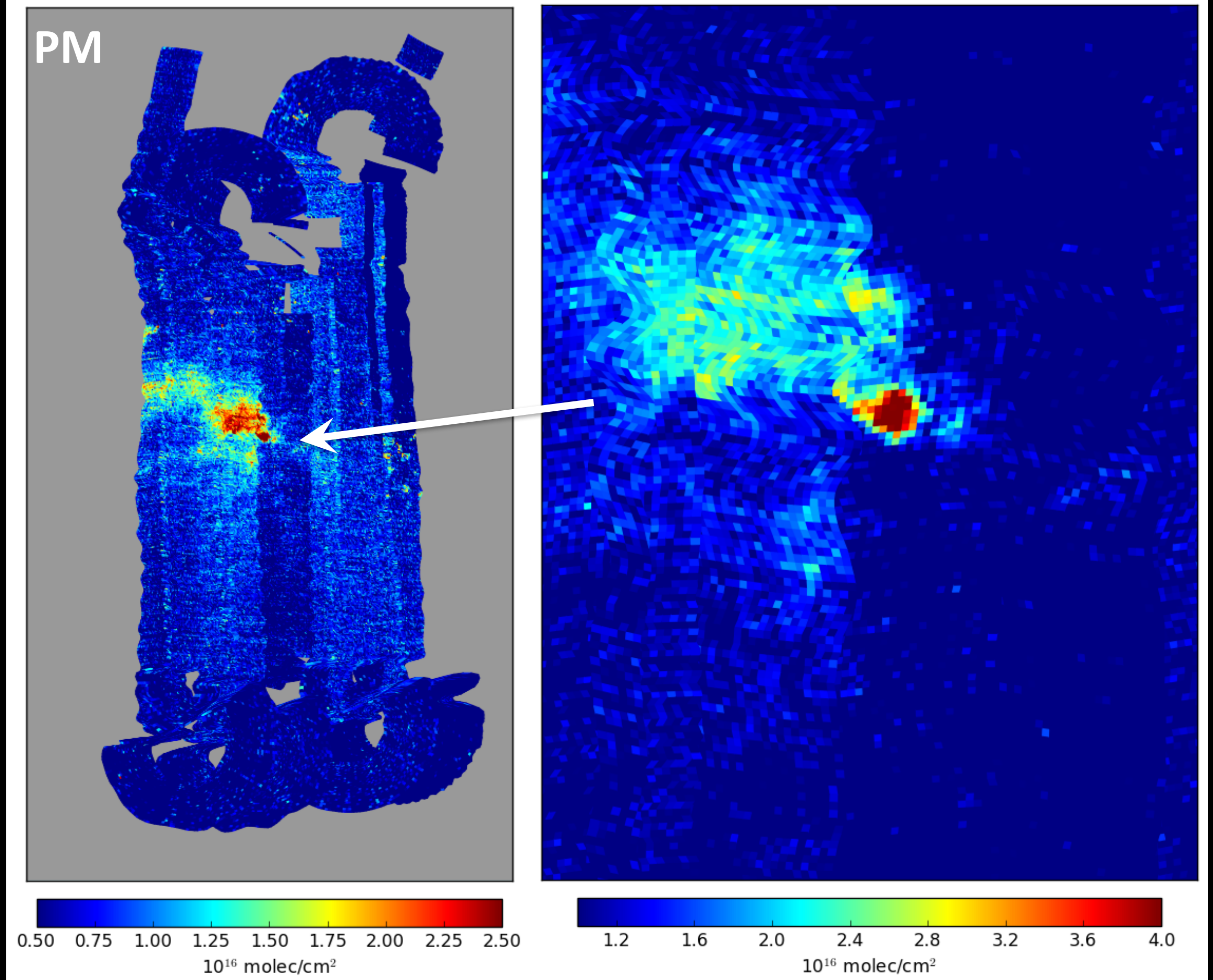
Denver 2014,
AM

NO₂ semi-slant
columns (slant
columns divided
by the cosine of
the solar zenith
angle)



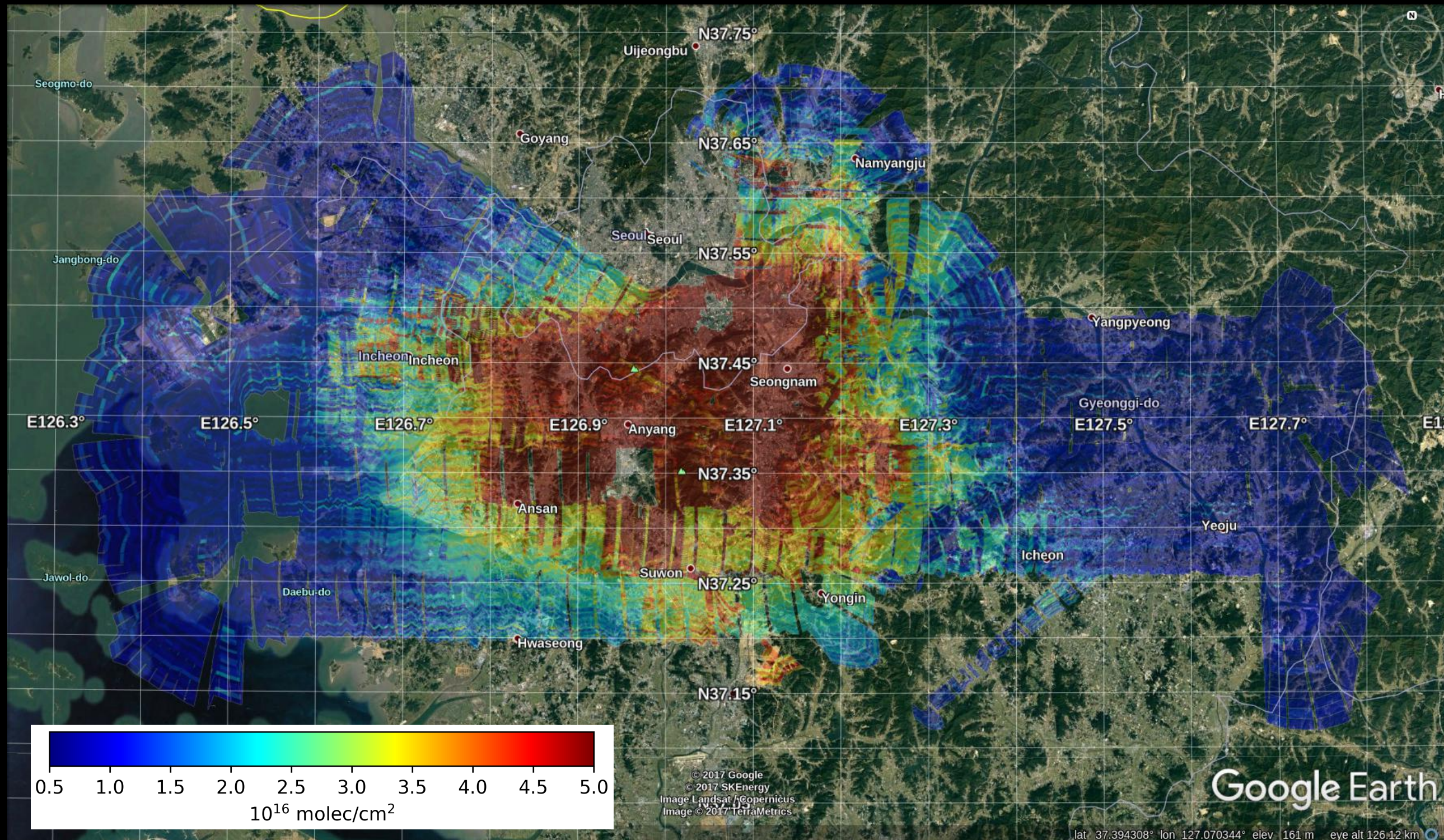
Denver 2014, PM

NO₂ semi-slant
columns (slant
columns divided
by the cosine of
the solar zenith
angle)



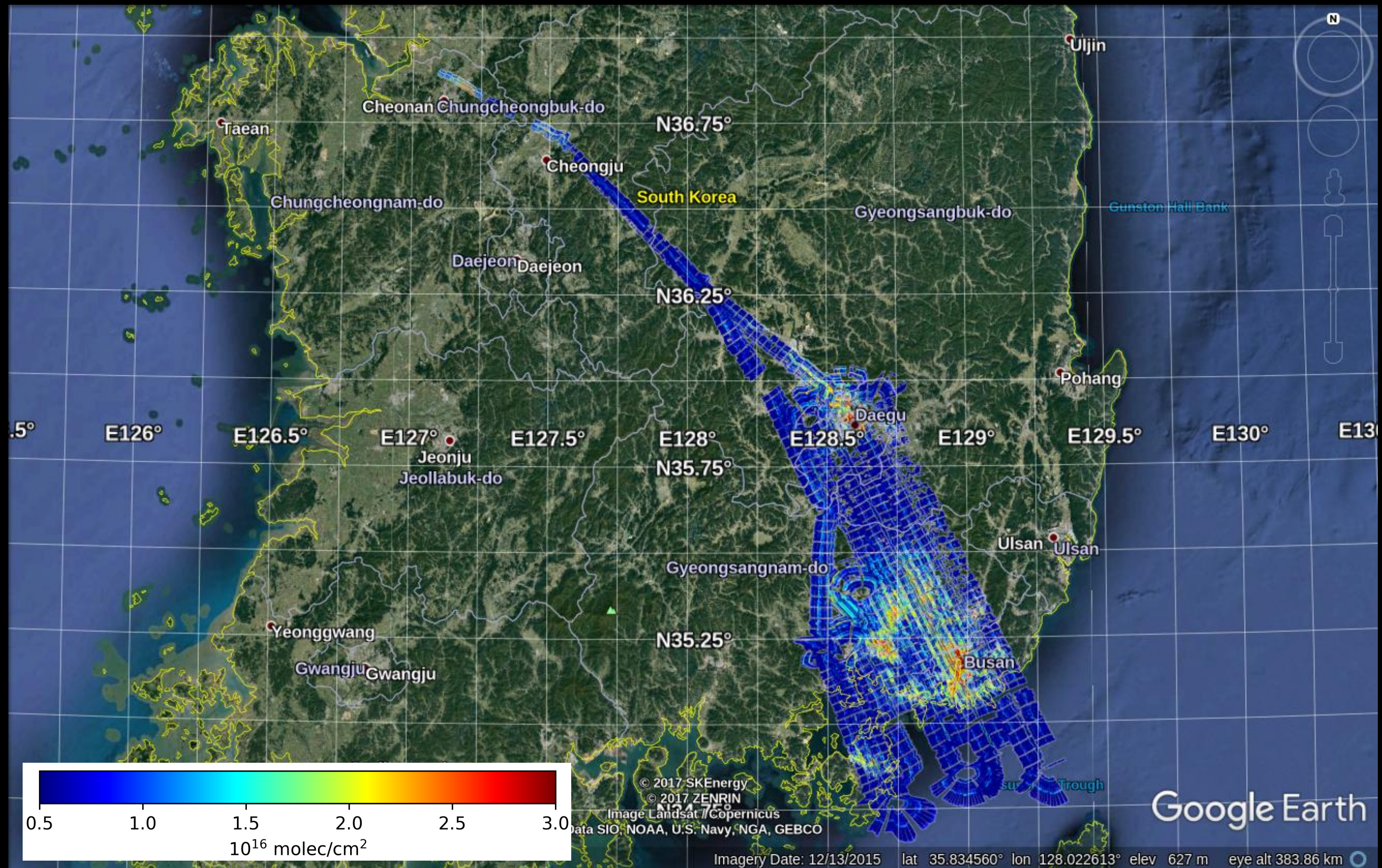
KORUS-AQ 2016, 2016-06-09, AM

NO₂ semi-slant columns (slant columns divided by the cosine of the solar zenith angle)



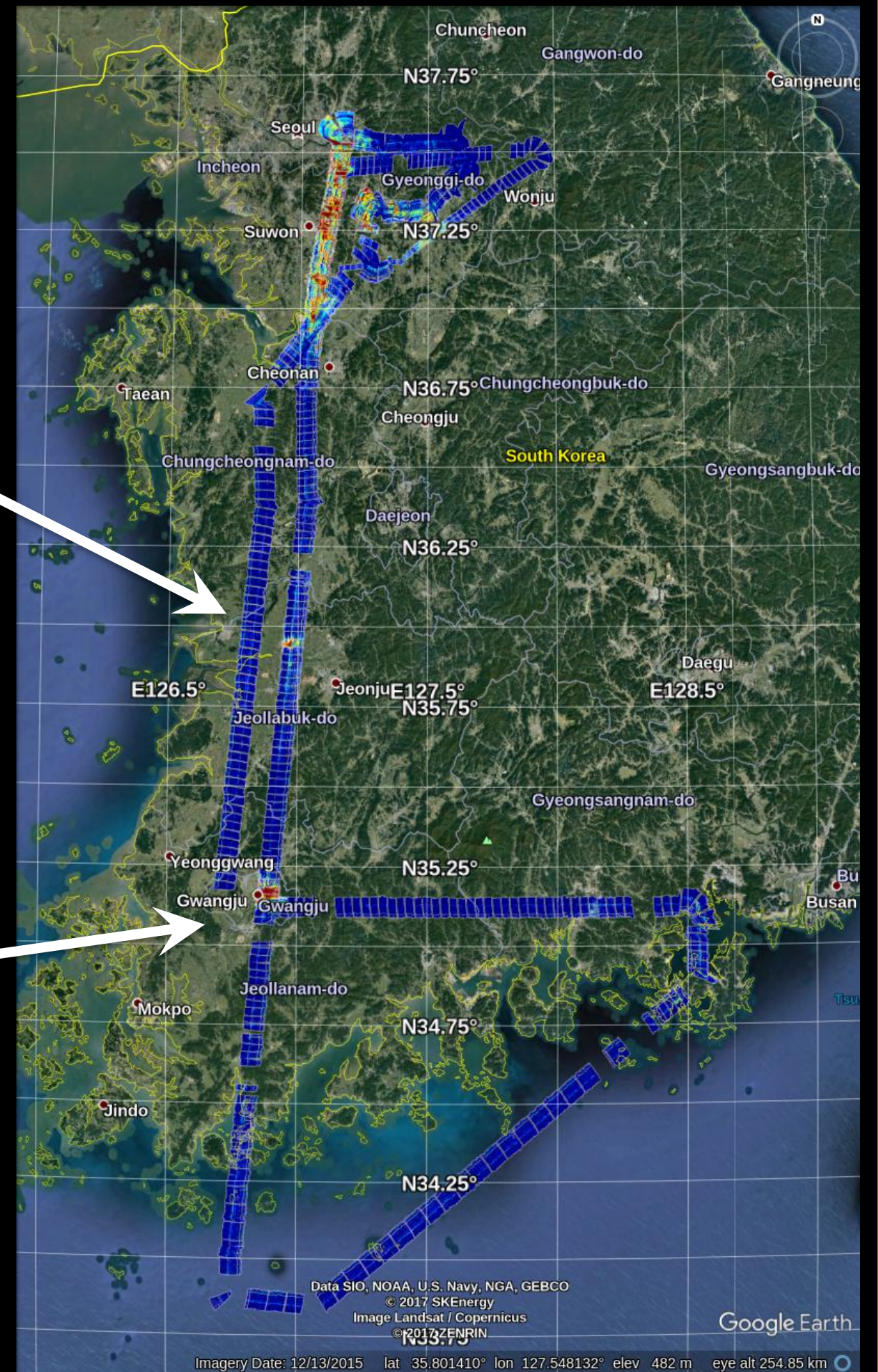
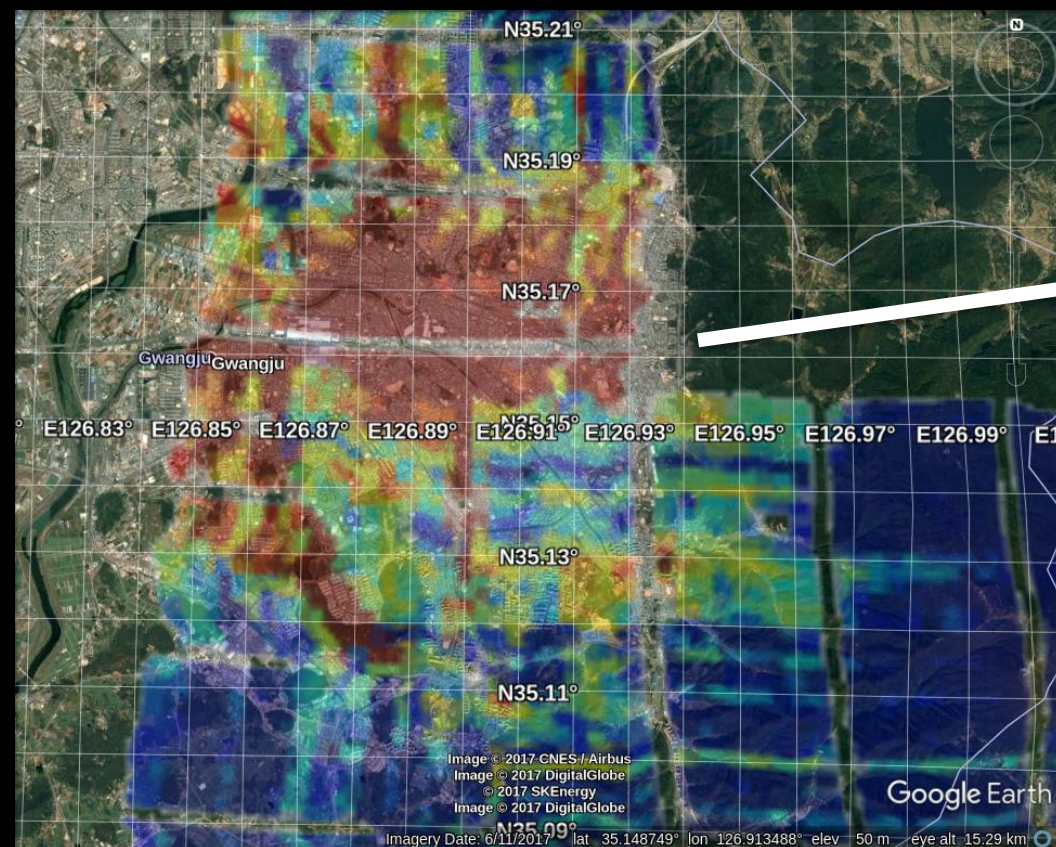
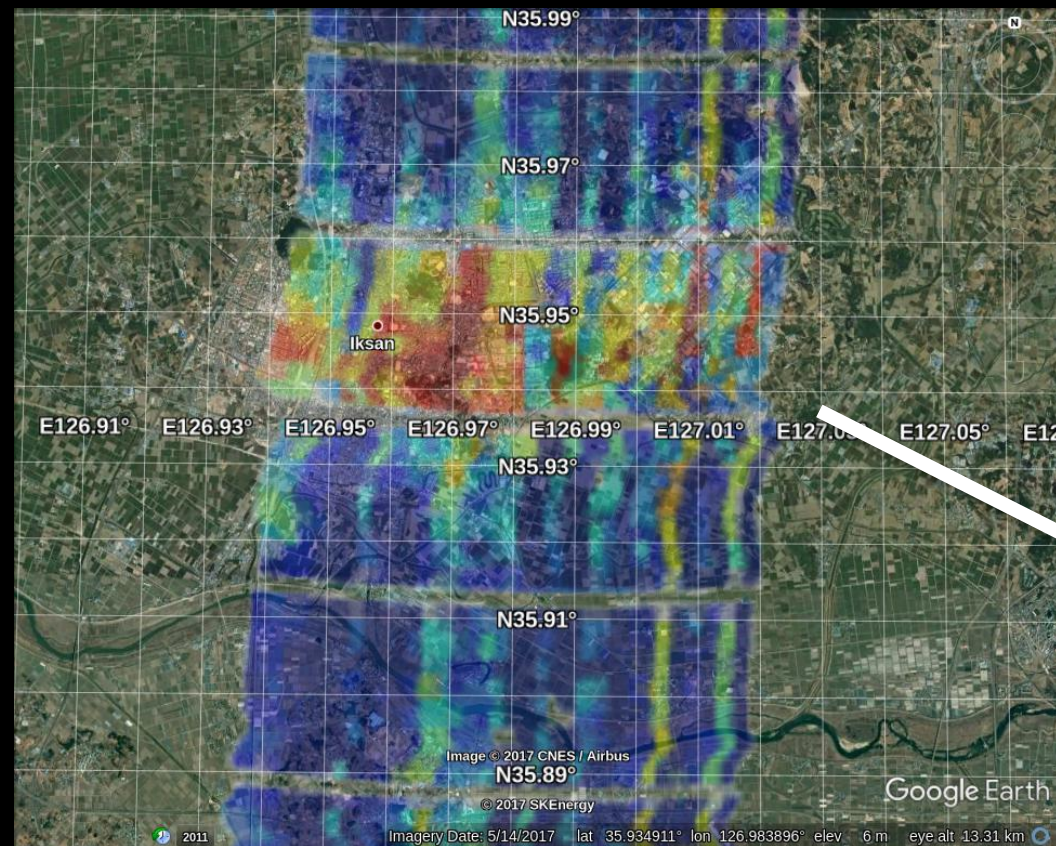
KORUS-AQ 2016, 2016-06-10, AM

NO₂ semi-slant columns (slant columns divided by the cosine of the solar zenith angle)



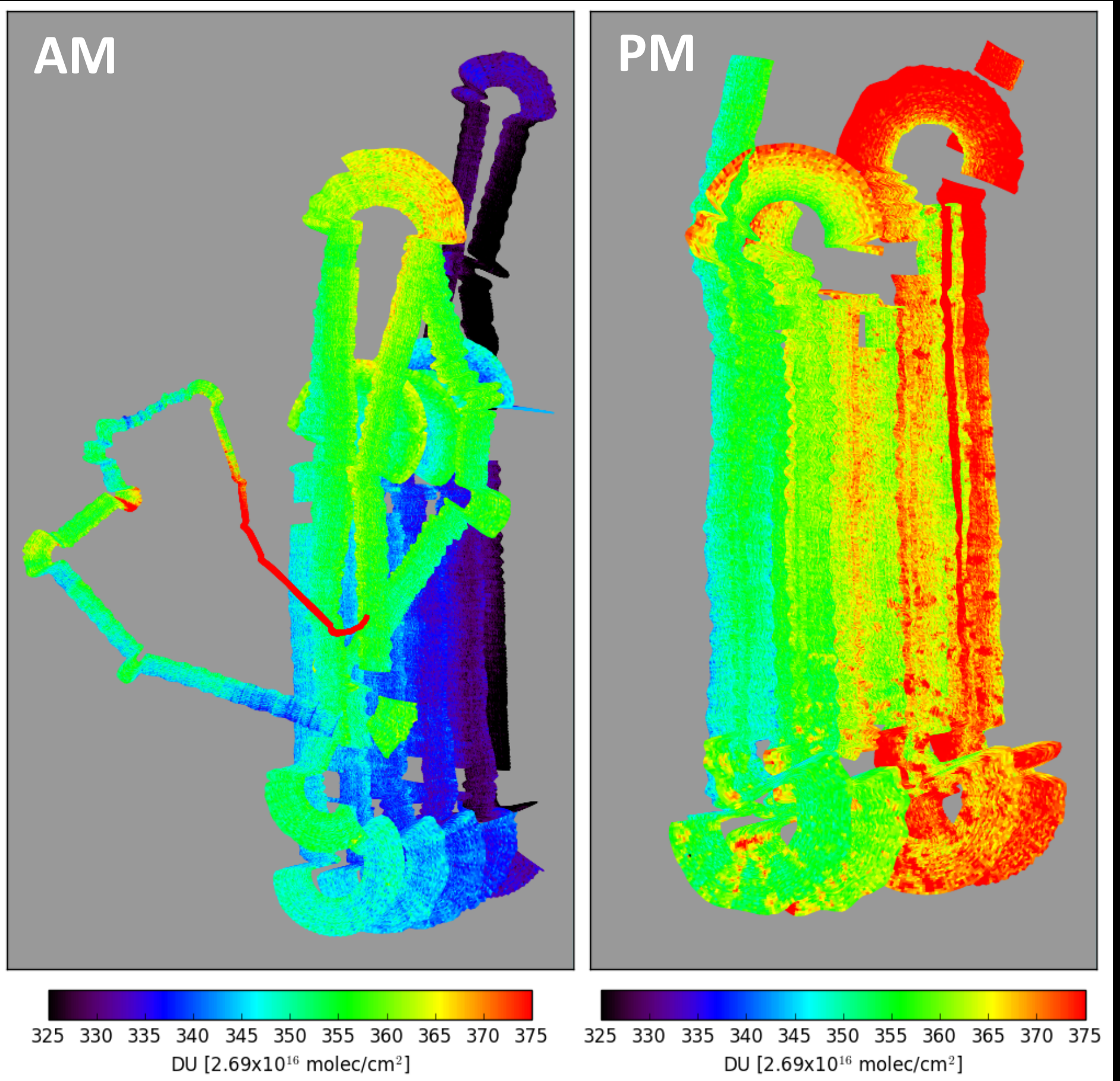
KORUS-AQ 2016, 2016-05-19, PM

NO₂ semi-slant columns (slant columns divided by the cosine of the solar zenith angle)



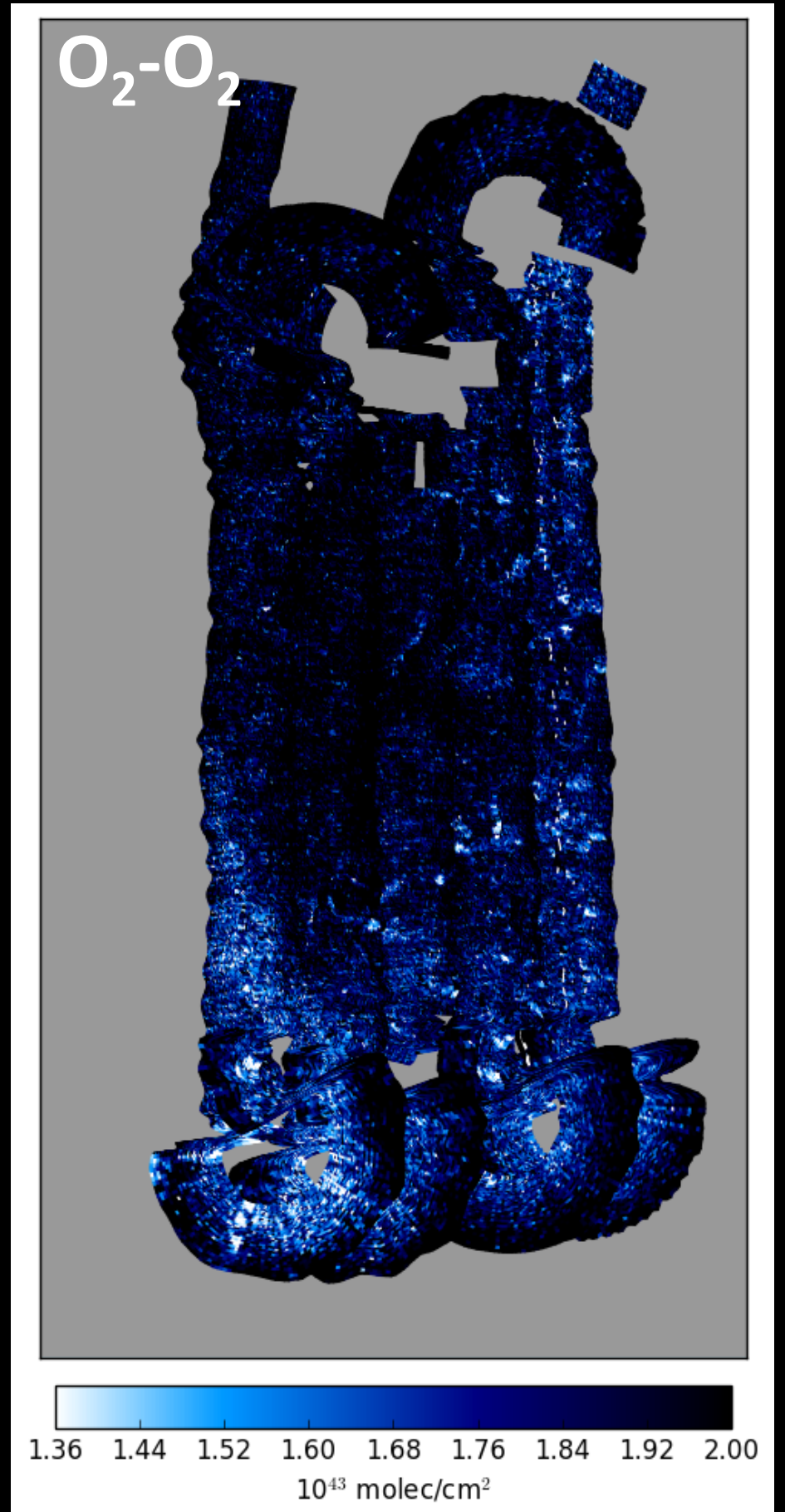
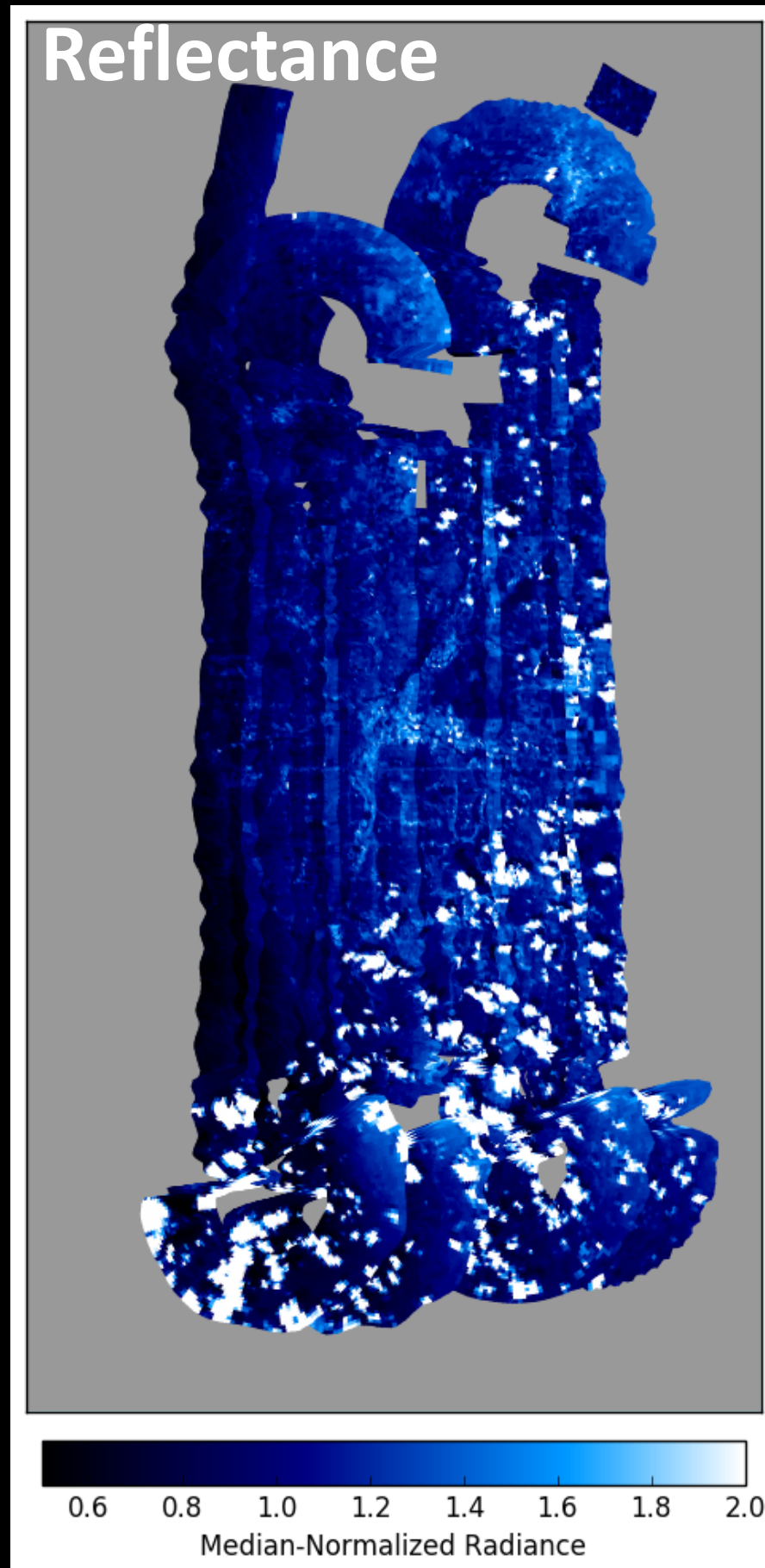
O₃ Columns, UV Channel

O₃ retrievals are still preliminary. The results from the UV channel exhibit significant along-track striping and a significant dependence on solar zenith angle/time of day. There is also a slight cross-track dependence, possibly induced by a residual difference in radiometric calibration between the eastern and western edge of the swath. Attempts to retrieve O₃ from the visible channel are as yet unsuccessful. The molecular absorption cross-sections of ozone past 400 nm contain much less differential structure compared to the UV, and low-order polynomial interferences from surface reflectance and atmospheric scattering are rendering the retrievals more complicated.



O₂-O₂/Clouds, Visible Channel

The afternoon flight was partially contaminated by clouds (most likely fair weather cumulus). The images show the normalized average radiance over the O₂-O₂ fitting window together with the retrieved O₂-O₂ columns (note reversed color scales). Reduction in the well-mixed oxygen dimer columns indicate the presence of optically thick clouds, which cut off the partial column below the cloud. Thinner clouds and aerosols can lead to enhanced atmospheric scattering and thus enlarged trace gas columns. The O₂-O₂ retrievals are still relatively noisy but they show the potential to serve as reliable cloud indicators and for use in air mass factor calculations.



Next Steps

The immediate next step is to improve the performance of the UV spectral fits of O_3 from the KORUS-AQ observations, followed by the completion of the interface between spectral fitting and fast radiative transfer, for an end-to-end total column retrieval. NO_2 will be the test bed for this implementation, since this retrieval product is currently the most mature.

Simultaneously, the outstanding issues the outstanding issues in the O_3 retrieval will be addressed towards the realization of an ozone profile algorithm. Combined UV/Visible ozone retrievals will depend on the level of cross-calibration between GeoTASO UV and Visible channels that can be achieved.

VOC retrievals of formaldehyde and glyoxal, are of lesser priority but will be revisited as the work on O_3 and NO_2 progresses.